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Visual Semiotics for Data Visualization in an Immersive Virtual Reality Environment

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Abstract*:* Visualization has long been a powerful tool to extract useful information from data, using vision, the most critical human sense. Current visualization tools are being increasingly challenged, due to the complexity, high-dimensionality, and high volume of emerging "big data." Immersive virtual reality (iVR) has been emerging as an alternative medium to visualize complex (big) data. iVR experiences can provide users with a comprehensive sense of physical presence in a non-physical world, in terms of interactive 3D visualization and egocentric view. This engaging nature of iVR environment allows users to efficiently use their human perceptual skills to explore complex (big) data including geographic data. While data visualization applications in VR are rapidly emerging, there is no comprehensive understanding on various visual components for geographic data/information visualization in VR. Hence, in this study, we propose visual semiotics of geographic data/information visualization in VR.

Keywords: Geovisualization, Visual semiotics, Data visualization, 3D visualization, Virtual environment, Virtual reality, VR, Immersive virtual reality

1. Extended Abstract

Visualization has long been a powerful tool to extract useful information from data, using vision, the most critical human sense (Verstraelen 2005, Thomas and Cook 2006). Current visualization tools are being increasingly challenged, due to the complexity, high-dimensionality, and high volume of emerging "big data" (Chen and Zhang 2014). While data mining techniques and 2D/3D visualization methods in traditional visual interfaces (e.g. 2D displays) have addressed many big data challenges, immersive virtual reality (iVR) has been emerging as an alternative medium to visualize complex (big) data (e.g. Kwon et al. 2016). iVR experiences can provide users with a comprehensive sense of physical presence in a non-physical world (Slater 1999), in terms of interactive 3D visualization and egocentric view. This engaging nature of iVR environment allows users to efficiently use their human perceptual skills to explore complex (big) data including geographic data (Nagel et al. 2008). However, past VR and 3D visualizations for abstract data within the literature have had mixed efficacy compared with 2D visualizations (Amini et al. 2015, Song et al. 2014), despite of considerable success in more direct representation of real world phenomenon (Byers and Woo 2015). User studies on visualization in VR have not proven yet that visualizations in VR is always more efficient than those in traditional visual interfaces (e.g. Sullivan 2016), in terms of task performance such as execution time and accuracy. One critical barrier to effective VR visualizations for geographic data and/or information is a lack of understanding on how to optimally map different types of data/information into appropriate visual variables and visual metaphors that are available in VR. Many interactive 3D visualizations in VR have been created using data/information visualization design principles intended for traditional visual media. VR however introduces many aspects for visualization that are not adequately accounted for in the traditional paradigms of geographic data/information visualization. VR visualizations take place in an artificial environment that not only enables another spatial dimension, but objects that can absorb, reflect, or emit light without regard for physical properties. This needs to be kept in mind when examining traditional approaches. For example, Bertin (1983) proposed the

proper use of visual variables (e.g. size, color, texture) for data/information visualization in Semiology of Graphics, but his suggestions are limited to visualizations "on a flat sheet of white paper of standard size and under normal lighting" (7, 1983 [2011 reprint]). MacEachren (1994) provided an expanded version of visual variable syntactics (e.g. transparency, orientation, arrangement) based on Bertin (1983)'s work; it was mainly focused on visual variables in 2D. Recently, Semmo et al. (2015) suggested design principles for 3D geospatial information visualization, and Helbig et al. (2014) proposed concepts and flows of 3D visualization of atmospheric information in VR. While data visualization applications in VR are rapidly emerging, there is no comprehensive understanding on various visual components for geographic data/information visualization in VR. Hence, in this paper, we propose visual semiotics of geographic data/information visualization in VR. We 1) identify a variety of visual components including 2D/3D static visual variables, 2D/3D dynamic visual variables, interactivity, and visual perspectives (point of view), 2) propose a typology of such visual components, and 3) discuss what types of visual components are appropriate to visualize certain types of geographic data/information in consideration of traits of a VR environment, including immersiveness and interactivity in VR. Finally, we illustrate the use cases of visual components in VR by implementing them in an actual VR environment with geographic data.

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